

## PROCESS FOR PRODUCING ELECTROPHORETIC DISPLAY

### FIELD OF THE INVENTION AND RELATED ART

The present invention relates to a production  
5 process of an electrophoretic display which effects  
display by moving charged particles.

In the electrophoretic display, the following  
points 1) to 3) are important in improving display  
characteristics, particularly suppressing display  
10 unevenness:

1) to uniformize an amount of electric charge  
possessed by charged particles in a dispersion liquid  
for migration,

2) to uniformize an in-plane density of the  
15 charged particles, and

3) to dispose the charged particles at a desired  
position.

In this regard, proposals have been made with  
respect to suppression of a charge in in-plane density  
20 of the charged particles after injection or  
disposition of the charged particles at a uniform in-  
plane density in, e.g., Japanese Laid-Open Patent  
Applications (Kokai) Sho 64-86117, (Kokai) Hei 2-  
223935 and (Kohyo) Hei 8-502599.

25 However, there was a limit in reducing a  
display unevenness only by uniformizing the charge  
amount and uniformizing the in-plane density of the

charged particles as described above.

#### SUMMARY OF THE INVENTION

Accordingly, an object of the present  
5 invention is to provide a process for producing an  
electrophoretic display with good image display  
qualities.

According to the present invention, there is  
provided a process for producing an electrophoretic  
10 display of the type wherein a dispersion liquid for  
migration and a plurality of charged particles are  
sandwiched between a first substrate and a second  
substrate, said process comprising:

a latent image forming step of forming an  
15 electrostatic latent image on an adsorption member,

a developing step of causing the adsorption  
member to contact the dispersion liquid in which the  
charged particles are dispersed, thereby to attach the  
charged particles together with the dispersion liquid  
20 onto a surface of the adsorption member on which the  
latent image is formed,

a transfer step of transferring the charged  
particles from the surface of the adsorption member to  
the second substrate together with the dispersion  
25 liquid, and

a sealing step of bonding the first substrate  
to the second substrate to seal the charged particles

and the dispersion liquid, therebetween.

These and other objects, features and advantages of the present invention will become more apparent upon a consideration of the following description of the preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1 to 4 are respectively a schematic illustration for explaining an embodiment of the process for producing an electrophoretic display according to the present invention.

Figures 5 and 6 are respectively a sectional view showing an embodiment of a structure of an electrophoretic display to be produced by the production process of the present invention.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the present invention will be described with reference to Figures 1 to 6.

(1) First, a structure of an electrophoretic display to be produced through the production process according to the present invention will be described with reference to Figures 5 and 6.

The electrophoretic display to be produced by the production process of the present invention

(indicated by D1 in Figure 5 and D2 in Figure 6) includes a pair of substrates 1a and 1b disposed with a predetermined spacing, a dispersion liquid 2 for migration (electrophoresis) disposed at the spacing  
5 between the substrates 1a and 1b, a plurality of charged particles 3 dispersed in the dispersion liquid 2, and a first electrode 4a (14a) and a second electrode 4b (14b) disposed along the dispersion liquid 2. Through these electrodes 4a and 4b (14a and  
10 14b), an electric field is applied to the dispersion liquid 2 to move the charged particles 3, thus effecting image display.

This display apparatus (electrophoretic display) may be of the transmission type (for  
15 recognizing an image by utilizing light transmitted through the display apparatus) or the reflection type (for recognizing an image by utilizing light reflected by the display apparatus). In the case of the transmission-type display apparatus, it is necessary  
20 to form the substrates 1a and 1b, the electrodes 4a, 4b, 14a and 14b, the dispersion liquid 2 and other members, of a light-transmission material. In the case of the reflection-type display apparatus, it is necessary to form the substrate and electrode(s) and  
25 other members to be disposed on the light incident side (i.e., a viewer side), of a light-transmission material.

As a material for the substrates 1a and 1b, it is possible to use glass; plastics, such as polyethylene terephthalate (PET) and polyether sulfone (PES); and metals, such as stainless steel. When the  
5 light transmission property is required, glass or the like may be used, and when a flexibility is ensured, a film of PET or PES or a thin plate of metal may be used.

The first electrode and the second electrode  
10 may be supported by different substrates 1a and 1b, respectively, as indicated by symbols 4a and 4b in Figure 5, or supported by one substrate 1b as indicated by symbols 14a and 14b in Figure 6. These electrodes may be formed of ITO (indium tin oxide) or  
15 metal such as Al, Ag and Ti. When the light transmission property is required. ITO or the like may be used, and when the light transmission property is not required, the metals may be used. When the electrode is used for displaying black, TiC may be  
20 used.

On the electrodes 4a, 4b, 14a and 14b, insulating layers 5a, 5b, 15a and 15b are disposed to cover the electrodes, respectively. The insulating layers 5a, 5b, 15a and 15b may be formed of organic  
25 materials, such as acrylic resin, polyimide resin, and polycarbonate, or of an inorganic film. In the case of the reflection-type display apparatus, the

insulating layer(s) disposed on the rear side may be formed as a scattering layer by adding alumina ( $\text{Al}_2\text{O}_3$ ) or titanium oxide ( $\text{TiO}_2$ ).

At the spacing between the substrates 1a and 1b, a partition member 6 may be disposed so as to define adjacent pixels. The partition member 6 may be formed of rubbers, such as silicone rubber, fluorocarbon rubber and acrylic rubber; or photosensitive resins, such as acrylic resin and polyimide resin.

As the charged particles, it is possible to suitably use particles comprising, as a main component, a polymer (resin) such as polystyrene or polyethylene, and as an additive, a colorant such as carbon; particles of pigments, such as titanium oxide and aluminum oxide; and polymer (resin)-coated or the like can be mixed in the charged particles as desired. A particle size of the charged particles may be in the rang of 0.1 - 15  $\mu\text{m}$ . The charged particles are charged electrically to a predetermined polarity.

As the dispersion liquid 2 for migration, it is possible to use a liquid, capable of appropriately charging the charged particles and having a low viscosity, such as silicone oil, xylene, toluene or isoparaffin. In order to match a specific gravity of the dispersion liquid 2 with that of the electrophoretic particles 3, it is possible to use a

dispersion liquid 2 having a larger specific gravity in combination, if necessary.

In the above described electrophoretic display (display apparatus), display is effected by  
5 utilizing a difference in color between the case of attracting the charged particles 3 to the first electrode 4a or 14a and the case of attracting the charged particles 3 to the second electrode 4b or 14b.

Accordingly, it is necessary to color the  
10 constitutional members of the display apparatus in advance.

For example, in the case of the electrophoretic display shown in Figure 5, the dispersion liquid 2 is colored a certain color, and  
15 the charged particles 3 are colored a color different from the certain color. When the charged particles 3 are attracted to the first electrode 4a, the color of the charged particles 3 is visually identified. On the other hand, when the charged particles 3 are  
20 attracted to the second electrode 4b, the color of the dispersion liquid 2 is visually identified.

In the case of the electrophoretic display shown in Figure 6, the dispersion liquid 2 is made transparent so that the charged particles 3 are  
25 visually identified from the substrate 1a side, and the charged particles 3 and a predetermined region (e.g., a region other than a region where the second

electrode 14b is disposed) are colored different colors each other. When the charged particles 3 are attracted to the first electrode 14a, the color of the charged particles 3 is visually identified. On the  
5 other hand, when the charged particles are attracted to the second electrode 14b, the color of the predetermined region is visually identified.

The display of image may be performed at a monicolor display mode, a two-color display mode, or a  
10 full-color display mode.

Herein, the monicolor display mode is such a mode that image display is performed at all the pixels by switching between first color and background color. The two-color display mode is such a mode that image  
15 display is performed by disposing pixels for effecting switching between first color and background color and pixels for effecting switching between second color and background color. The full-color display mode is such a mode that, e.g., image display is performed by  
20 disposing pixels for effecting switching between first color and background color, pixels for effecting switching between second color and background color, and pixels for effecting switching between third color and background color.

25 In the case of performing the two-color display mode or the full-color display mode, it is possible to adopt a method wherein the color of

charged particles 3 is changed pixel by pixel (e.g.,  
red/white display is performed by using a plurality of  
set of two adjacent pixels including a pixel at which  
the charged particles 3 are colored red and another  
5 pixel at which the charged particles 3 are colored  
white); a method wherein the color of the dispersion  
liquid 2 is changed pixel by pixel; and a method  
wherein a color filter is disposed.

Next, an embodiment of a driving method for  
10 the electrophoretic display used in the present  
invention will be described.

In the case of the electrophoretic display  
shown in Figure 5, display is performed by applying a  
voltage between the electrodes. For example, the  
15 first electrode 4a is grounded and the respective  
second electrodes 4b are supplied with a positive or  
negative voltage when the charged particles 3 are  
positively charged, the charged particles 3 are moved  
onto the electrode having a relatively lower electric  
20 charge. At this time, it is possible to effect white  
display if the charged particles 3 are white and  
attracted to the first electrode 4a. On the other  
hand, if the charged particles 3 gather on the second  
electrode 4b, the color of the dispersion liquid 2 can  
25 be displayed. The color of the dispersion liquid 2 is  
selected so that it can sufficiently hide the color of  
the charged particles 3.

In the case of the electrophoretic display shown in Figure 6, display is performed by applying a voltage between the electrodes. For example, the first electrode 14a is grounded and the respective  
5 second electrodes 14b are supplied with a positive or negative voltage when the charged particles 3 are negatively charged, the charged particles 3 gather onto the electrode having a relatively higher electric charge. At this time, if the charged particles 3 and  
10 the second electrode 14b are black and the charged particles 3 are moved onto the first electrode 14a, it is possible to effect dark black display. The resultant contrast at this time largely depends on an areal ratio between the first and second electrodes  
15 14a and 14b. For this reason, it is necessary to reduce an exposed area of the second electrode 14b relative to that of the first electrode 14a in order to enhance the contrast. Generally, the areal ratio of the second electrode to the first electrode may  
20 be 1:2 to 1:4. The applied voltage may vary depending on the amount of electric charge of the charged particles 3 and an electrode pitch but may generally be 1 - 100 V.

(2) Next, a production apparatus for the  
25 electrophoretic display of the present invention will be described.

The production apparatus for the

electrophoretic display according to the present invention is used for producing such an electrophoretic display that a dispersion liquid 2 for migration and charged particles 3 are filled on a first substrate 1a. As shown in Figure 1, a production apparatus A1 includes a storage tank 20 containing the charged particles 3 and the dispersion liquid 2, on adsorption member 21 capable of forming thereon an electrostatic latent image, and an electrostatic latent image forming means 23 for forming an electrostatic latent image on the adsorption member 21. In the production apparatus A1, the adsorption member 21 on which the electrostatic latent image is formed by using the electrostatic latent image forming means 22 is immersed into the dispersion liquid 2 in the storage tank 20 to attach the charged particles 3 to the adsorption member 21, and then the charged particles 3 attached to the adsorption member 21 are transferred onto a first substrate B.

The adsorption member 21 may be designed to be movable to at least three positions including a first position opposite to the electrostatic latent image forming means 22, a second position at which the adsorption member 21 is immersed in the dispersion liquid 2, and a third position opposite to the first substrate B. More specifically, the adsorption member

21 may be desired so that the electrostatic latent image is formed at the first position, developed at the second position, and transferred onto the first substrate at the third position.

5           The adsorption member 21 has a roller shape as shown in Figure 1 and is rotated to the first, second and third positions in this order in a direction of an arrow but may have other shapes (such as a plate shape shown in Figure 3 as a member 31, and  
10   a polygonal prism). In the case of using the roller-shaped adsorption member 21, the storage tank 20 and the electrostatic latent image 21. Further, it is possible to use a photosensitive member as the adsorption member 21.

15           The electrostatic latent image forming means may include a charger 220 for uniformly electrically charging the adsorption member 21, and a light irradiation device 221 for irradiating the adsorption member 21 with light.

20           The adsorption member 21 may be provided with charge-removing means therefor after the transfer operation and cleaning means for removing residual charged particles 3 and residual dispersion liquid 2 remaining on the adsorption member 21 after the  
25   transfer operation.

          Incidentally, the storage tank 20 shown in Figure 1 is disposed at a lower portion of the

adsorption member 21 and has an opening which is largely opened to the adsorption member 21 so that the adsorption member 21 can be immersed in the storage tank 20 but may be designed as a storage tank 30 as shown in Figure 3(a) so that it is provided with a nozzle 30a at its bottom portion and is moved horizontally above an adsorption member 31.

(3) Then, the production process of electrophoretic display of the present invention will be described.

The production process of electrophoretic display according to the present invention principally comprises an operation of filling the dispersion liquid 2 for migration and the plurality of charged particles 3 and the first substrate 1a (or 1b) and an operation of bonding the second substrate 1b (or 1a) to the first substrate 1a (or 1b) so as to sandwich the dispersion liquid 2 and the charged particles 3 therebetween. More specifically, the filling operation of the dispersion liquid 2 and the charged particles 3 onto the first substrate (B shown in Figure 1) includes an electrostatic latent image forming step of forming an electrostatic latent image on an adsorption member 21 (or 31), a developing step of attaching the charged particles 3 and the dispersion liquid 2 onto the adsorption member 21 (or 31), and a transfer step of transferring the charged

particles 3 and the dispersion liquid 2, which have been attached to the adsorption member 21 (or 31), onto the first substrate B. The bonding operation performed thereafter includes a step of bonding the  
5 second substrate to the above treated first substrate B.

Herein, the "first substrate" means a substrate by which the charged particles 3 are adsorbed through the transfer step, and the "second  
10 substrate" means a substrate which has not been subjected to the transfer step.

In the present invention, the transfer of the charged particles 3 and the dispersion liquid 2 may be effected onto either of a display substrate (disposed  
15 on a viewer side) and a rear substrate (disposed on a side opposite from the viewer side). In other words, either of the first substrate and the second substrate may be used as the display substrate or the rear substrate.

20 In the case of producing the electrophoretic display shown in Figure 5, the transfer may be effected onto either of the substrate 1a (or which the first electrode 4a is formed) and the substrate 1b (or which the second substrate 4b is formed), as the first  
25 substrate. In the case of producing the electrophoretic display shown in Figure 6, the transfer may be effected onto either of the substrate

1 (or which the first and second electrodes 14a and  
14b are formed) and the substrate 1b (on which the  
first and second electrodes 14a and 14b are not  
formed), as the first substrate. However, in a  
5 preferred embodiment, the transfer is effected onto  
the substrate provided with the electrode(s) (the  
substrate 1a shown in Figure 5 or the substrate 1b  
shown in Figure 6) in such a manner that at least one  
of the first and second electrodes are formed on the  
10 first substrate before subjected to the transfer step  
and supplied with a voltage for transfer in the  
transfer step. Further, immediately before the  
transfer step, the electrostatic latent image  
remaining on the adsorption member may be removed. By  
15 doing so, it is possible to remove an adsorption force  
of the charged particles 3 to the adsorption member,  
whereby the transfer of the charged particles 3 to the  
adsorption member can be performed smoothly.  
Incidentally, a (closest) gap between the substrate  
20 surface and the adsorption member may preferably be 1  
- 500  $\mu\text{m}$ .

The surface of the adsorption member may  
preferably have a wettability to the adsorption liquid  
identical to that of the surface of the first  
25 substrate to which the dispersion liquid is to be  
transferred together with the charged particles. More  
specifically, it is preferable that a surface tension

of the adsorption member is substantially equal to that of the first substrate or that a difference between these surface potentials is not more than 10 dyn/cm<sup>2</sup>. As a result, after the adsorption step, the dispersion liquid for migration is subjected to the transfer step in such a state that an adsorption surface is wet by the dispersion liquid, so that the dispersion liquid is transferred to the first substrate together with the charged particles and the second substrate is bonded to the first substrate with no filling step of the dispersion liquid.

In the case where adjacent pixels are partitioned by the partition member 6 as described above, the partition member 6 may preferably be formed on the first substrate B before subjected to the transfer step.

Further, in the case where the charged particles 3 are disposed at pixels so that the color thereof is changed pixel by pixel, it is preferable that a plurality of adsorption members are used for the number of colors of the charged particles 3 (21 shown in Figure 4) and are respectively subjected to the electrostatic latent image forming step and the developing step describe above, whereby the charged particles 3 of different colors are attached to the adsorption members, respectively. The above described transfer step is performed with respect to the

respective adsorption members, whereby the charged particles of different colors are transferred together with the dispersion liquid 2 onto the first substrate B described above and thereafter, the above describe  
5 bonding step of substrates is effected.

After completion of the transfer step, a charge removing step of removing the electrostatic latent image by charge-removing electric charges from the surface of the adsorption member 21 or 31 or a  
10 cleaning step of removing the charged particles 3 and the dispersion liquid 2 remaining on the adsorption member 21 or 31 may be effected. The removal of the electrostatic latent image may be performed by irradiating the adsorption member with light.

15 On the other hand, the developing step described above may be effected by immersing the adsorption member in the dispersion liquid 2 in which the charged particles 3 are dispersed. By immersing the adsorption member in the dispersion liquid 2, the  
20 charged particles 3 are electrophoretically moved toward the electrostatic latent image in accordance with a potential gradient created by the electric-charge latent image (electrostatic latent image). In the process of this migration, it is possible to  
25 effect classification of the charged particles 3. Hereinbelow, the classification method for the charged particles 3 will be described.

One of the classification methods is a method wherein a time of immersion of the adsorption member 21 in the dispersion liquid 2 for migration is restricted. The amount of electric charge of the charged particles 3 migrating in the dispersion liquid 2 vary and the migration speed thereof is different depending on the charge amount, so that the charged particles 3 having a smaller charge amount has a relatively slower migration speed. For this reason, by setting the limit to the immersion time of the adsorption member in the dispersion liquid, it becomes possible to control a distribution of charge amount of the charged particles 3 attached to the adsorption member. In that case, as shown by a symbol 21a in Figure 2, a adsorption member side electrode is disposed on the adsorption member side, and as shown by a symbol 23, an adsorption control electrode is disposed on the dispersion liquid side, so that the adsorption of the charged particles 3 to the adsorption member 21 can be controlled based on application of a voltage to these electrodes (the charged particles 3 can be classified by controlling the migration speed). Hereinbelow, details thereof will be described. The voltage applied to the adsorption control electrode may have a polarity identical or opposite to that of the charged particles 3 in the dispersion liquid 2. In the case of the

identical polarity, the migration speed of the charged particles is accelerate to shorten the immersion time. In the case of the opposite polarity, it is possible to suppress the adsorption of the charged particles 3 to the adsorption member.

Another method is a method wherein a rotation speed of the adsorption member 21 is controlled.

There is a relationship between a magnitude of charge amount of the charged particles 3 and an adsorption

force of the charged particles 3 to the adsorption member 21. There is such a tendency that the

adsorption force of the charged particles 3 to the adsorption member 21 is larger with a larger charge amount. On the other hand, by the rotation of the

adsorption member 21, convection of the dispersion liquid 2 occurs at the boundary of the adsorption

member. As the rotation is faster, the convection at the adsorption member boundary becomes intense. Based on these relationships, by the influence of the

convection of the dispersion liquid 2 in the vicinity of the adsorption member boundary created by utilizing the rotation of the adsorption member 21, it is

possible to remove the charged particles having a weaker adsorption force through peeling-off thereof

from the adsorption member 21. Accordingly, it is possible to control the charge amount distribution of the charged particles 3 attached to the adsorption

member 21 by controlling the rotation speed.

In the case where the color of the charged particles 3 is changed pixel by pixel in the two-color or full-color display mode, it is preferable that the  
5 above described developing step is performed by immersing the adsorption member in the dispersion liquid 2, in which the charged particles 3 and an ultraviolet polymerizable compound are dispersed, to attach not only the charged particles 3 and the  
10 dispersion liquid 2 but also the ultraviolet polymerizable compound to the adsorption member; the partition member 6 is formed on the first substrate B; the charged particles 3 and the ultraviolet polymerizable compound are transferred together with  
15 the dispersion liquid 2 onto the first substrate B by the transfer step; and the ultraviolet polymerizable compound is irradiated with ultraviolet rays before performing the above-mentioned bonding step, thereby to form a film. Hereinbelow, details thereof will be  
20 described.

An important factor in the case where the color of the charged particles is changed pixel by pixel is that the charged particles of different colors are not mixed with each other by preventing the  
25 charged particles 3 from migrating toward another pixel portion. This is because if the once arranged particles are moved from the predetermined area, it

becomes impossible to create a predetermined color at the time of display. When the irradiation of ultraviolet rays is performed as described above, the ultraviolet polymerizable compound is cured after  
5 phase-separated from the dispersion liquid 2, so that the above described film is formed and creates a closed space with the partition member 6, thus suppressing movement of the charged particles 3 toward another pixel portion. Incidentally, the ultraviolet  
10 polymerizable compound before the curing may preferably be liquid and is required to have a small affinity with the charged particle 3 and not to dissolve the charged particles 3 as its characteristics. As such an ultraviolet  
15 polymerizable compound, it is possible to utilize, e.g., 2-hydroxyethyl methacrylate, 1,4-butanedioldiglycidyl ether diacrylate, polyethylene glycol monomethacrylate (e.g., Blenmer PE series, mfd. by NOF Corp.).

20           Next, a specific embodiment of the production process of the electrophoretic display will be supplementally described.

          In the case of the electrophoretic display shown in Figure 5, the second electrode 4b is formed  
25 in a pattern on the surface of the substrate 1b and thereon the insulating layer 5a is formed as desired, and the partition member 6 is further formed thereon.

On the other substrate 1a, the first electrode 4a and the insulating layer 5a are formed. Thereafter, the transfer step etc. described above is effected. For the bonding of substrates, an adhesive (which is cured  
5 by heat or ultraviolet rays) is used.

In the case of the electrophoretic display shown in Figure 6, the first electrode 14a, the insulating layer 15a, the second electrode 14b, the insulating layer 15b and the partition member 6 are  
10 formed on the surface of the substrate 1b.

Thereafter, the above mentioned transfer step etc. is formed. An adhesive (which is cured heat or ultraviolet rays) is used for bonding the substrates.

Next, effects of this embodiments will be  
15 explained.

According to this embodiment, it is possible to control the charge amount and the arrangement density of the charged particles attached to the first substrate B, so that an electrophoretic display with  
20 good image display qualities can be produced.

Hereinbelow, the present invention will be described more specifically based on Examples.

(Example 1)

In this example, a vertical movement-type  
25 electrophoretic display D1 shown in Figure 5 was prepared.

On a rear substrate 1b, a second electrode 4b

was formed at a portion corresponding to each pixel area, and the second electrode 4b was coated with an insulating layer 5b.

On an entire surface of the other display  
5 substrate 1a, a first electrode 4a was formed, and an insulating layer 5a was formed on the surface of the first electrode 4a. As the display substrate, 10  $\mu\text{m}$ -thick polycarbonate (PC) film was used and as the rear substrate, 0.5 mm-thick stainless steel sheet was  
10 used. As the first electrode 4a, a transparent electrode of ITO (indium tin oxide) was used and as the second electrode 4b, an Al electrode was used. As the insulating layers 5a and 5b, a film of transparent acrylic resin was used. On the surface of the  
15 insulating layer 5b of the rear substrate 1b, a 20  $\mu\text{m}$ -thick partition member 6 of photosensitive epoxy resin was formed.

Then, onto the insulating layer 5a of the display substrate 1a, charged particles 3 and a  
20 dispersion liquid 2 for migration were attached by using a production apparatus as shown in Figure 1.

As an adsorption member of this apparatus, an adsorption roller 21 to be rotationally driven was used and around the adsorption roller 21, a charger  
25 220 for electrically charging the roller surface to a uniform potential, a laser light irradiation device 221, and a storage tank 20 containing the charged

particles 3 and the dispersion liquid 2 were disposed.

When the adsorption roller 21 was rotated in a clockwise direction, the roller surface was successively charged by the charger 220 and irradiated with light by the laser light irradiation device 221, whereby an electrostatic latent image was formed (electrostatic latent image forming step).

Thereafter, the adsorption roller 21 was immersed in the dispersion liquid 2 to attach the charged particles 3 onto the roller surface (developing step).

On the other hand, by corona discharge, the surface of the insulating layer 5a of the display substrate 1a was electrically charged to the same polarity as the electrostatic latent image, and the display substrate 1a was moved in an indicated arrow in synchronism with rotation of the adsorption roller 21. At this time, a closest gap between the display substrate 1a and the adsorption roller 21 was set to 50  $\mu\text{m}$ . As a result, the charged particles 3 were transferred together with the dispersion liquid 2 onto the display substrate 1a surface (transfer step).

Incidentally, in the storage tank 20, the charged particles 3 having a larger charge amount were liable to be attached to the roller surface and classified during the process. Further, the charged particles 3 were appropriately stirred in the storage tank 20 to suppress sedimentation of the charged

particles 3.

On the other hand, after completion of the transfer step, an appropriate amount of the dispersion liquid 2 was added to the display substrate 1a.

5           Thereafter, the rear substrate 1b was bonded to the display substrate 1b to seal the charged particles 3 and the dispersion liquid 2.

In this example, as the dispersion liquid 2, a dispersion liquid colored with a blue dye was used.  
10          Further, the charged particles 3 was principally comprised of white titanium oxide mixed with a negative charge control agent, and thus showed a negative chargeability in the dispersion liquid 2.

In the thus prepared electrophoretic display,  
15          the charge amount of the charged particles 3 filled therein were controlled to exhibit uniform configuration (arrangement) density.

When the electrophoretic display was driven by applying a voltage (potential difference) of 20 V  
20          between the first and second electrodes 4a and 4b, it becomes possible to effect good display of images with no display unevenness caused by a change in particle density distribution.

(Example 2)

25           In this example, an electrophoretic display D1 having structure shown in Figure 5 was prepared in the same manner as in Example 1 except that the

transfer of the charged particles 3 was effected by using a transfer apparatus shown in Figure 2.

More specifically, an adsorption control electrode 23 was disposed opposite to the adsorption roller 21 in this storage tank 20, and a voltage was applied between the electrode 21a on the adsorption roller side and the adsorption control electrode 23 to control a migration speed of the charged particles 3.

According to this example, it was possible to effect classification of the charged particles in a short time. Further, the same effect as in Example 1 was also attained.

(Example 3)

In this example, an electrophoretic display having a structure shown in Figure 5 was prepared in the same manner as in Example 2 except that an electrostatic latent image was removed by irradiating the adsorption member 21 with light at the time of transfer of the charged particles 3 onto the first substrate.

As a result, an attractive force from the adsorption roller 21 to the charged particles 3 was reduced or removed, so that it becomes possible to smoothly move the charged particles 3 from the surface of the adsorption roller 21 to the first substrate.

In this example, the adsorption roller 21 after completion of the transfer step was subjected to

a cleaning step to remove the charged particles 3.  
The adsorption roller 21 may further be subjected to a  
charge removing step for effecting charge removal from  
the electrostatic latent image.

5               When a potential difference of 10 V was  
applied between the first and second electrodes 4a and  
4b to drive the above-prepared electrophoretic  
display, it was possible to display good images free  
from display unevenness caused due to particle density  
10 distribution change.

(Example 4)

In this example, a horizontal movement-type  
electrophoretic display D2 shown in Figure 6 was  
prepared.

15               On an almost entire surface of a rear  
substrate 1b of polyethylene terephthalate (PET), a  
first electrode 14a of Al was formed. On the surface  
of the first electrode 14a, a lower insulating layer  
15a (as a white scattering layer) of acrylic resin  
20 containing titanium oxide ( $\text{TiO}_2$ ) was formed. Further,  
on the surface of the insulating layer 15a, a second  
electrode 14b of Ti was formed in an area  
corresponding to each pixel area (minute area) and  
thereon, an upper insulating layer 15b of transparent  
25 acrylic resin was formed. Thereafter, at a boundary  
portion between adjacent pixel areas, a partition wall  
6 of silicone rubber having a height of 30  $\mu\text{m}$  was

formed.

Then, onto the upper insulating layer 15b of the rear substrate 1b, charged particles 3 and a dispersion liquid 2 for migration were attached by  
5 using an apparatus shown in Figure 3.

The charged particles 3 were particles of polystyrene-polymethylmethacrylate copolymer resin containing carbon black (particle size: 1 - 2  $\mu\text{m}$ ; negatively chargeable in the dispersion liquid 2).  
10 The dispersion liquid 2 was isoparaffin (trade name: "Isopar", mfd. by Exxon Corp.) containing succinimide (trade name: "OLOA 1200", mfd. by Chevron Corp.) as a charge control agent.

The apparatus included an adsorption member  
15 31 in the form of a plate and an electrode 31a disposed backside of the adsorption member 31 as shown in Figure 3(a). The apparatus further included a charger 220, a laser light irradiation device 221, and a storage tank 30 which were disposed opposite to the  
20 adsorption member 31. The storage tank was provided with a nozzle 31. The storage tank was provided with a nozzle 30a at its bottom.

When the charger 220 and the laser light irradiation device 221 were scanned, an electrostatic  
25 latent image was formed (electrostatic latent image forming step), and onto the electrostatic latent image, the charged particles 3 and the dispersion

liquid 2 were attached from the storage tank 30. In the storage tank 30, the charged particles 3 were stirred so as not to be settled down to the bottom.

After a predetermined amount of the charged particles 3 were adsorbed by the adsorption member 31 as described above and until a subsequent transfer step, the dispersion liquid 2 was sprayed onto the surface of the adsorption member 31 so as not to be evaporated during the period (not shown).

Thereafter, as shown in Figure 3(b), the rear substrate 1b was disposed opposite to the adsorption member 31 with a spacing of about 50  $\mu\text{m}$  so that the dispersion liquid 2 was filled in the spacing. A voltage of 100 V was applied between the electrodes 14a and 31a to move the charged particles 3 and the dispersion liquid 2 toward the rear substrate 1b.

After completion of the transfer step, the adsorption member 31 was subjected to the charge removing step and the cleaning step.

A display substrate 1a of polycarbonate (PC) was bonded to the rear substrate 1b to prepare an electrophoretic display.

In the thus prepared electrophoretic display, the filled charged particles 3 were charge-controlled and disposed at a uniform particle density even on the flexible substrate 1b. For this reason, when the electrophoretic display was driven by applying a

potential difference of 12 V between the first and second electrodes 14a and 14b, it became possible to effect good image display without causing display unevenness by a change in particle density distribution.

(Example 5)

In this example, an electrophoretic display having a structure shown in Figure 5 was prepared. As charged particles 3, color particles of yellow, magenta and cyan were used and disposed pixel by pixel by utilizing an apparatus shown in Figure 4.

In the same manner as in Example 1, the second electrode 4b and the insulating layer 5b were formed on the rear substrate 1b, and the first electrode 4a and the insulating layer 5a were formed on the display substrate 1a.

Then, the charged particles 3 and the dispersion liquid 2 were attached onto the insulating layer 5a of the display substrate 1a by using the apparatus shown in Figure 4.

As shown in Figure 4, the apparatus included three adsorption members 21 to be rotationally driven. Around each of the adsorption members 21, a charger 220, a laser light irradiation device 221, a storage tank 20 and UV irradiation device were disposed. In the storage tank 20, the charged particles 3 of an associated color were stored. The electrostatic

latent image forming step, the developing step and the transfer step were performed in the same manner as in Example 1. In the transfer step, the display substrate 1a was moved in a direction of an indicated arrow, whereby three-color charged particles 3 were successively transferred onto the display substrate 1a.

In the storage tank 30, 2hydroxyethyl methacrylate (ultraviolet polymerizable compound) was added in advance in the dispersion liquid 2 so as to be transferred onto the substrate 1a together with the charged particles 3 and the dispersion liquid 2. At the time of transfer, electric charges of a polarity identical to that of the electrostatic latent image were provided to the display substrate 1a by corona discharge, and a closest gap between the display substrate 1a and the adsorption roller 21 was set to 50  $\mu\text{m}$ . The transferred dispersion liquid 2 was irradiated with ultraviolet rays from the UV irradiation device 25, whereby a film of the ultraviolet polymerizable compound was formed at the surface of the dispersion liquid 2 to seal the charged particles 3 and the dispersion liquid 2.

The adsorption roller 21 after completion of transfer step was subjected to the cleaning step to effect removal of the charged particles 3 etc.

Thereafter, the rear substrate 1b was bonded

to the display substrate 1a to seal the charged particles 3 etc., thus preparing an electrophoretic display.

According to this example, the respective  
5 color charged particles 3 are filled in associated pixels, respectively, without causing color mixing therebetween. As a result, the charge amount and the distribution density of the charged particles 3 were also appropriately controlled to provide good display  
10 qualities. When the electrophoretic display was driven by applying a potential difference of 10 V between the first and second electrodes 4a and 4b, it was possible to display good images with no display unevenness caused due to particle density distribution  
15 irregularity.

As described hereinabove, according to the present invention, it is possible to appropriately control the charge amount and the configuration density of the charged particles attached to the first  
20 substrate, so that it becomes possible to produce an electrophoretic display with good image density qualities.